REDUCTION OF WATER CONSUMPTION BY MEANS OF PITOMETER SURVEY AND CONSTANT INSPECTION[1]

By George C. Andrews

In 1897 the Buffalo Common Council decided it more advantageous to its citizens to install more pumps and give practically an unlimited supply of water than to control consumption by means of meters. It is hardly necessary to add that this decision was made contrary to sound engineering advice. "Free water" is a slogan that often appeals to the unthinking. It would be interesting to speculate on what that decision has cost the citizens of Buffalo in the past twenty-two years. Suffice it to say that in 1903 the Bureau of Water had a bonded debt of $3,699,382.00, while it was $12,141,524.00 in 1917. From that date until 1917 it was a race between the unchecked waste in both mains and houses and the pumps.

In 1903 there was one pumping station with a daily capacity of 183,000,000 gallons. In 1917 there were two pumping stations with a combined daily capacity of 330,000,000 gallons. Coincident with the increased pumping capacity large distributing mains were laid. During this period the per capita consumption had ranged between 302 and 339 gallons per day. Of this practically 100 gallons was for industrial use.

In 1916 the city government was altered and a commission of five men elected to govern the city. Their platform was an economical and efficient city government, and one of the early efforts was an investigation as to means to reduce the city water consumption. As all water used must be pumped from Lake Erie against a head of 140 to 204 feet, a reduction in pumpage would make an immense saving in coal used for fuel. Various methods were considered and in the Spring of 1917 it was decided to have a pitometer survey made of a small section of the city with the idea of covering the whole city later should this section show satis-

[1] Read before the Buffalo convention June 10, 1919.

factory results. The question of metering was considered, but rejected on various grounds, some of which were the popular local prejudice against metering, the length of the time to meter the city completely, there being over 76,000 ummetered and active services, extensive changes in plumbing required in many of the poorer types of dwellings should meters be installed, and the heavy initial investment required for meters, while the pitometer method promised early results.

Figure 1 shows by months graphically the rapidly increasing yearly consumption from 1913 to 1917. Table 1 gives some statistics which supplement the information in the diagram.

To facilitate the work and also that definite records could be obtained of water consumption in different points, the city was

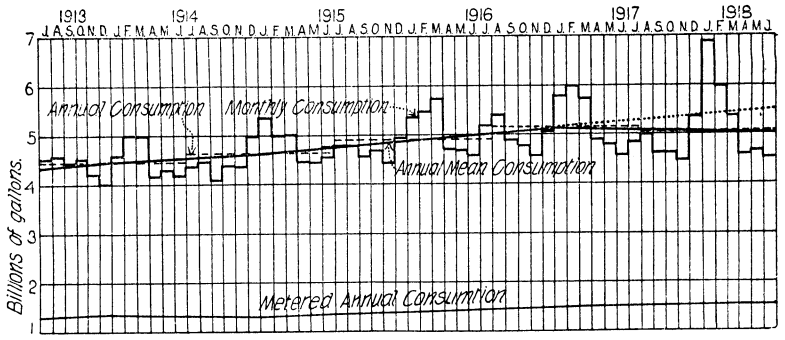

FIG. 1. MONTHLY CONSUMPTION OF WATER, 1913–1918 (SEE TABLE 1)

divided into ten sections, no two of which were similar in character, and the work completed by sections.

Section 1 included manufacturing use, poor, good, and high grade residential districts.

Section 2 is an old residential section with most of the buildings antedating the modern sewer and water service. In this section the toilets are usually of the so-called anti-freezing type installed in a shed in the rear of the house. The waste in this section was tremendous.

Section 3 is a portion of the city sub-divided in the nineties when water mains, sewers and services were laid. This section is only now being developed. The residences built are of fair construction. In this section the rock lies close to the surface and in many streets

water mains and house services are laid in the sewer trench. The value of the pitometer was proven in this section, as ever-leaking unfinished supplies which were discharging into the sewers were discovered and stopped. Along Fillmore Avenue quarries had been opened years ago and water from a broken 16-inch main discharging into the face of the pit had for years furnished excellent water for men and teams working in the quarry.

Section 4 is principally high class residential, such as the Delaware Park section. The western portion, however, has heavy manufacturing use of water and poor class dwellings. Three-fourths of this section is built on rock strata close to the surface.

Section 5 is high class residential, principally, with the eastern portion of middle-class dwellings. No manufacturing use of water.

TABLE 1

Water used and wasted in Buffalo from July, 1913, to June, 1919, inclusive

PERIOD	ANNUAL PUMPAGE	QUANTITY METERED	QUANTITY USED BY FLAT-RATE CONSUMERS, OR WASTED
	gallons	*gallons*	*gallons*
July, 1913, to June, 1914.....	53,330,674,000	16,176,835,000	37,153,839,000
July, 1914, to June, 1915.....	55,262,784,000	15,548,187,000	39,714,597,000
July, 1915, to June, 1916.....	58,514,254,240	16,666,042,000	41,848,212,240
July, 1916, to June, 1917.....	61,490,593,540	17,722,530,000	43,768,063,540
July, 1917, to June, 1918.....	61,017,090,980	18,019,927,500	42,997,163,480
July, 1918, to June, 1919.....	49,482,000,000	18,243,000,000	31,239,000,000

Section 6 takes in the heart of the business section of the city. The northern portion is composed of middle class dwellings, but 80 per cent of the water is used commercially.

Section 7 contains poorer class dwellings and has a large manufacturing use of water. All the big packing-houses and stockyards are included in this section.

Section 8 includes most of the water front of the city, with large manufacturing plants and commercial use of water. It has a poor class of dwellings, and is the oldest section of the city.

Sections 9 and 10 have middle class dwellings, with some large steel mills on the outskirts. Railroad yards are large consumers in these sections.

The theory of a pitometer survey may be briefly described as follows: A certain section of the mains is isolated by closing all but one of the boundary valves. A special corporation cock is inserted

on the main feeding this district through the open valve. The main is traversed and the velocity of the water determined by the instrument inserted in the main through the corporation cock. Gaugings are recorded on sensitive paper for forty-eight hours and from the velocities shown the flow computed. As all the water entering this section passes the instrument the amount measured must be the supply to the district. The interesting or indicating feature of these records is the relation between the minimum night rate, which is usually found between 12.00 and 3.00 a.m., and the total twenty-four hour consumption. A high night rate, unless accounted for industrially, means leaky fixtures or breaks in mains.

As the isolation of a section is apt to leave some industries just within and without the district short on water pressure, causing complaints of low pressure, a map is kept in the office of the Superintendent of Maintenance on which all valves closed are indicated by a red-headed pin. By this means one can at a glance determine if a complaint of lack of pressure is due to the pitometer work or to some other cause. These pins for closed valves are corrected each morning.

After the total measure of a district is made, sub-division work is started. Sub-division is the determination of the consumption block by block, and is always done at night. The pitometer is set at the gauging point and the district shut off block by block, the time of each shut-off being noted. By comparing the time with the consumption shown on the photo-chart at the corresponding time, the rate for each block can be determined. This is a very important feature of the pitometer work, as by comparing the consumption for the different blocks one knows immediately where the inspection of fixtures will give the greatest result. It is an especially valuable feature for the control of the house waste after a survey has once been made. By means of the pitometer and proper sub-division, house to house inspections can give results twice as quickly as though no pitometer were used, as efforts will be confined to blocks where the sub-division indicates the greatest results are to be obtained.

Immediately after the sub-division work was completed, inspectors were placed in the district and house to house inspection made.

To make the survey, an engineer in charge and four assistants were employed. Three trucks with gangs of four were constantly engaged and one clerk assigned to this work to keep the records. Twelve of the regular city inspectors made the house to house inspec-

tions. Later, as more of the city was covered, twenty temporary inspectors were engaged.

One of the assistant engineers made the district measurements, and two were constantly engaged on sub-division. One assistant engineer tested the meters and fire lines. During the winter months two men worked in the office.

The inspection for house waste is of great value, and a large percentage of the total waste eliminated is directly due to inspection. However, proper control must be exercised or the results will be indifferent.

From 1906 until 1915, the department employed men to stop house waste, but had no control over them by means of district measurements. During this period the per capita consumption was practically stationary, although the annual consumption increased.

As the sub-divisions showed waste in practically every block, a system of inspection records was developed. Inspectors worked in pairs and a report on every house and service made. Where leaks were discovered, a repair notice was left. Two weeks later a second inspection was made of all places where notice to repair was served. If repairs had not been made at that time, a second repair notice was left and a re-inspection made three days later, at which time water was turned off unless all plumbing was in good shape. The years of unlimited use and waste of water had rendered most people indifferent to the condition of the plumbing in their houses and at first considerable complaints were made at the so-called arbitrary ruling of the Bureau. However, these soon ceased as the results of the survey became apparent and in the majority of cases splendid co-operation was secured.

The inspectors tested first the house fixtures, and then if these were all right, tested with the aquaphone at the curb-box for service leaks. If house waste was found, the stop-cock at the house was closed before testing for service leaks. On their inspection report blanks, leaks were listed as service, faucet, toilet, etc., and a notice showing the nature of the leak served. A record of the number of people on each service was also reported. After the house inspection in a district was completed, the pitometer was again used to record the flow in different blocks in the sub-division. Where the night rate was still excessive, investigation for underground leaks was started. The determination of underground leaks is

largely a matter of skill, judgment and experience. By sub-dividing by blocks the leak can be located as to the block, but then the operator must find it by skill and judgment. If service pipes and boxes have been installed the aquaphone can give one the approximate location, and by driving a steel rod to the main the leak can be closely located. In only a few cases was it necessary to excavate more than one hole to find the leak.

Probably the most difficult work in this line was on Northland Avenue, in Section 3, where a night rate of 755,000 gallons was shown on one block. As there were practically no houses, and only one factory, which was metered and did not account for but a fraction of the flow, all indications pointed to a large joint leak or cracked pipe. In this street the pipe is laid in the sewer trench, which was excavated through rock. When the street was paved in 1893 house services had been placed every sixty feet. No large main leak was encountered, but seven service leaks were discovered and shut off at the main, which accounted for 700,000 gallons, or practically the entire waste. The corporation cocks had in nearly every instance been destroyed and water was discharging directly into the sewer. No indications of these leaks appeared on the street surface.

As work was completed in each division a permanent map was filed in the office, showing gauging points for the instrument and valves on boundary points. On this map is recorded the date of the first measurement, the 24-hour consumption and minimum night rate, and the same record of the second measurement. It is the intent of the Bureau of Water to continue the pitometer work as a special department and regular measurements will be taken at varied intervals, and these maps will facilitate the work greatly. All inspectors' reports are filed by streets and can be instantly referred to. As soon as a section was completed, a full report on it was submitted by the engineer-in-charge. This report gave a general summary of the work with certain specific recommendations to meet the conditions for the sections. These reports are filed so as to be available for future reference.

The report for Section 4 showed the following facts:

Total flow before inspection, gallons per twenty-four hours	17,936,000
Minimum night rate, gallons	14,912,000
Percentage of night rate to total flow	86.2

Inspection of all buildings on this section showed 3444 leaky fixtures divided as follows: faucets, 1064; toilets, 2380. It also disclosed 280 leaky services, which were repaired by the owners; 8 unfinished supplies, which were discharging into the sewer, were dug up and plugged. Also, one broken 6-inch main was uncovered and repaired.

After the house inspection and underground work was completed a re-measurement was taken with the following results: Reduction in daily consumption, 3,780,000 gallons; reduction in night rate, 3,910,000 gallons.

On account of the desire to reduce the pumpage as quickly as possible, so as to conserve coal as a war measure, no intensive work was attempted and the city was surveyed as rapidly as consistent with good work. It is highly probable that the results in this section could have been bettered had more time been devoted to it. However, by extending the work rapidly large leaks in other districts were detected and stopped in the time which might have been devoted to more intensive work in this section. It is expected that the work to be done in this section this summer will materially better the above result.

The efficiency of the survey as a means of reducing water consumption is shown by the monthly consumption chart, figure 2, which is a continuation of figure 1. Attention is called to the gradually increasing yearly consumption, as shown by the line AA, which in 1916-1917 showed a daily consumption of 168,000,000 gallons. Had no effort been made to check this the line indicates for the present year a daily pumpage of 186,000,000 gallons.

However, starting in July, 1917, which was co-incident with the start of the survey, each month shows a decrease in pumpage when compared with the same month in the preceding year except for the extremely cold months of December, 1917, and January and February, 1918. This chart brings out very clearly two conditions more or less peculiar to Buffalo. The summer months are usually higher than the monthly mean, while the months of December, January and February are excessively greater. Buffalo's homes are usually set well back from the street and surrounded by a grass plot. This not only applies to the homes of the well-to-do, but to the poorer classes as well. Practically half of the water bills have a sprinkling charge, indicating that the occupant uses a hose for sprinkling a lawn or street. From 5.00 to 9.00 o'clock on summer

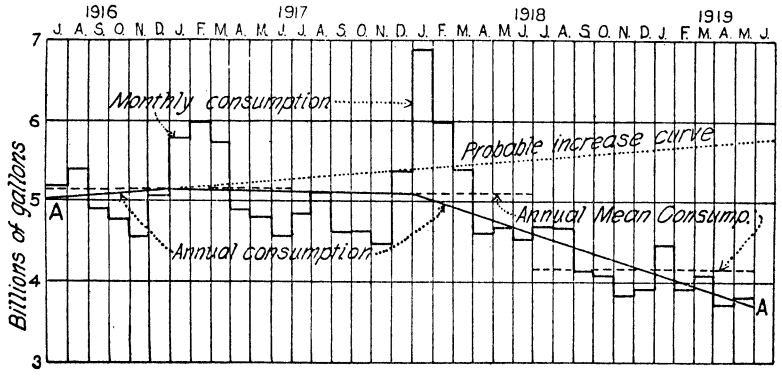

FIG. 2. WATER CONSUMPTION IN 1916–1919 (SEE TABLE 1)

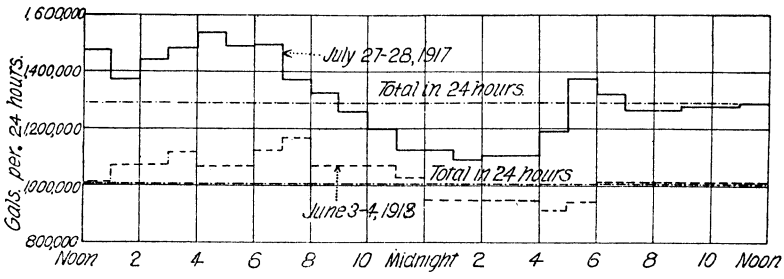

FIG. 3. CONSUMPTION IN A RESIDENTIAL DISTRICT WITH DWELLINGS OF A POOR CLASS, WITHOUT CELLARS AND GENERALLY WITH ANTI-FREEZING TOILETS. THE ONLY REDUCTION POSSIBLE IN TWELVE MONTHS WAS STOPPING UNDERGROUND LEAKAGE

	First measurement	*Second measurement*
Daily consumption, gallons	1,287,000	1,003,000
Minimum night rate, gallons	1,080,000	910,000
Population	4,670	4,670
Number of taps	667	667
Miles of main	6.2	6.2
Consumption per capita, gallons	275	214
Consumption per tap, gallons	1,929	1,503
Consumption per mile of main, gallons	214,500	167,166

nights, the department is apt to have close to its peak loads of the day at the stations, and the water used for sprinkling is enormous in the aggregate.

Besides this use in the summer time there is an excessive waste in the winter from the anti-freezing closet. Most of these have been installed in the older sections of the city and the majority

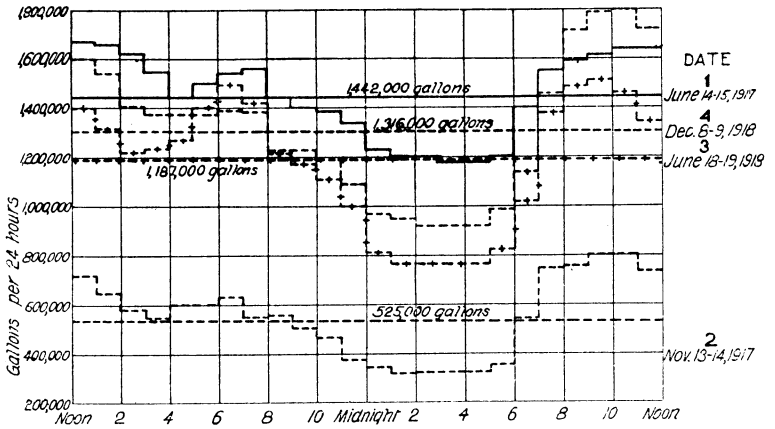

FIG. 4. CONSUMPTION IN A RESIDENTIAL DISTRICT WITH MIDDLE-CLASS DWELLINGS, THE ONLY COMMERCIAL CONSUMPTION BEING IN STORES

	First measurement before waste investigation	*Second measurement 5 months after survey*	*Third measurement twelve months later*	*Fourth measurement eighteen months later*
Daily consumption, gallons	1,442,000	525,000	1,187,000	1,316,000
Minimum night rate, gallons	1,175,000	316,000	775,000	925,000
Consumption per capita, gallons	128	46	105	116
Consumption per tap, gallons	536	195	441	489
Consumption per mile of main, gallons	75,900	27,639	62,473	69,263

Population, 11,273; number of taps, 2,600; miles of main, 19.2.

are in bad repair. The records show close to 10,000 of them still in use. Besides these the plumbing installation in many of the cheap houses has been such that to keep pipes from freezing it is necessary to allow water to run. The effect of this is shown by winter months' consumption.

More careful inspection of new plumbing is now being made and the anti-freezing closet is being gradually eliminated. When these are all done away with a great source of waste is gone.

Our first section was surveyed in 1917, and this year re-measurements have been taken. These show that there is a more or less gradual return of the waste first eliminated, depending wholly on the character of dwellings, as shown in figure 4. In all sections the consumption was less than it was two years ago at the time of the

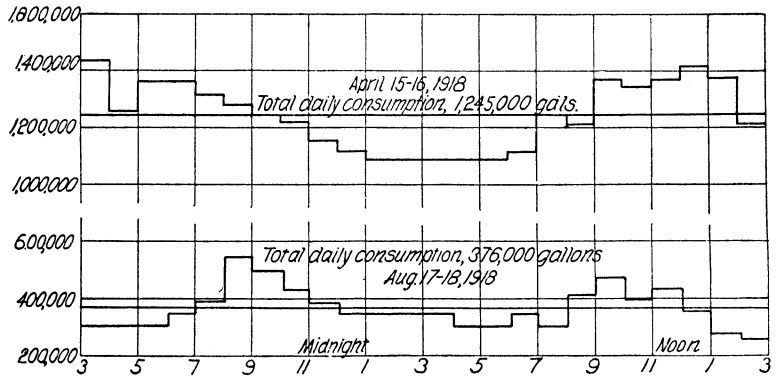

FIG. 5. DAILY CONSUMPTION IN HIGH-CLASS RESIDENTIAL DISTRICT BEFORE AND AFTER WASTE INVESTIGATION

	Daily consumption, gallons	*Minimum night rate, gallons*	*Consumption per capita, gallons*	*Consumption per tap, gallons*	*Consumption per mile of main, gallons*
Before investigation, April 15–16, 1918.....	1,245,000	1,185,000	394	1411	65,000
After investigation, August 17–19, 1918	376,000	260,000	119	426	19,790

Population, 3158; number of taps, 882; miles of main, 19. Very little house waste but a reduction of 869,000 gallons per day was made by stopping underground waste not showing on the surface.

first measurement. The author estimates that effects of the result of the survey will be from one to three years as far as house waste is concerned. All underground leaks stopped are a permanent saving.

In the sections completed the house waste stopped is estimated at 18,000,000 gallons, while the underground waste stopped was 12,000,000 gallons by actual measurements.

It is the intention to measure and sub-divide the entire city once in two years and to inspect completely as often. Of course measurements and inspections will be made oftener in the sections where waste is greatest. To control waste more fully in these sections meters will be placed gradually.

However, to reduce the pumpage quickly was imperative. The author knows of no other way which would have given results so quickly. To install meters would have taken from three to five years and the reduction would not have been felt for some time, at

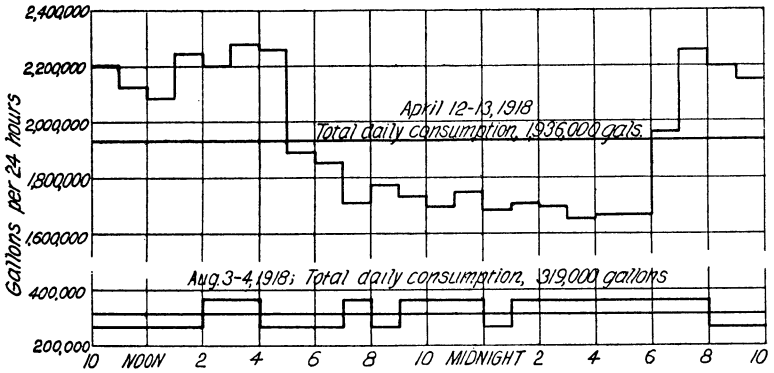

FIG. 6. DAILY CONSUMPTION IN A MIDDLE-CLASS RESIDENTIAL AND MANUFACTURING DISTRICT BEFORE AND AFTER WASTE INVESTIGATION

	Daily consumption, gallons	*Minimum night rate, gallons*	*Consumption per capita, gallons*	*Consumption per tap, gallons*	*Consumption per mile of main, gallons*
Before investigation, April 12–13, 1918..	1,936,000	1,655,000	1.001	4,976	16,500
After investigation, August 3–4, 1918..	319,000	260,000	165	820	2,726

Population, 1934; number of taps, 389; miles of main, 11.7.

least not for the first six months when the size of the bill would have brought the waste of water home very forcibly to the householder.

Figures 7 and 8 show the daily consumption divided as well as possible for the years 1917 and 1919. In this chart the legitimate household use is assumed at 50 gallons per capita per day. The industrial use is assumed to be the total metered use, as practically all industries are metered. This use is practically 100 gallons per capita per day. It is hard to account for such a large industrial use of water per capita in a city the size of Buffalo. In the author's

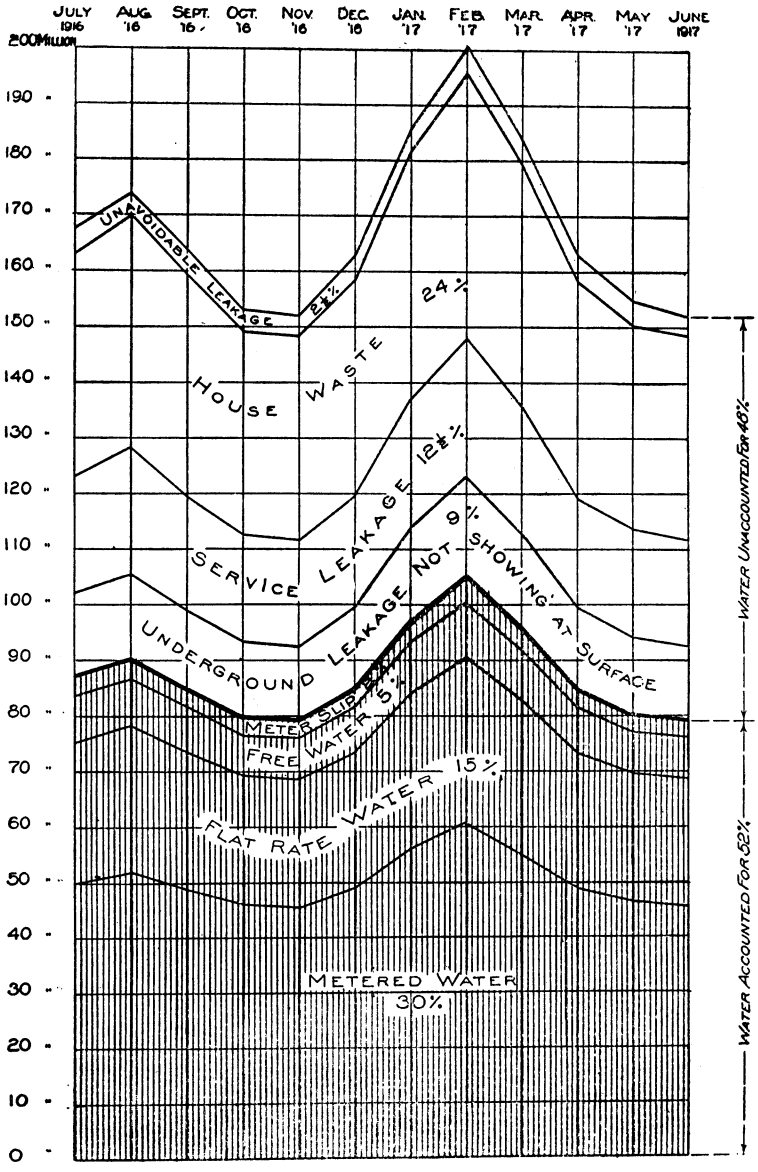

FIG. 7. SUB-DIVISION OF USE AND WASTE OF WATER IN 1916–1917

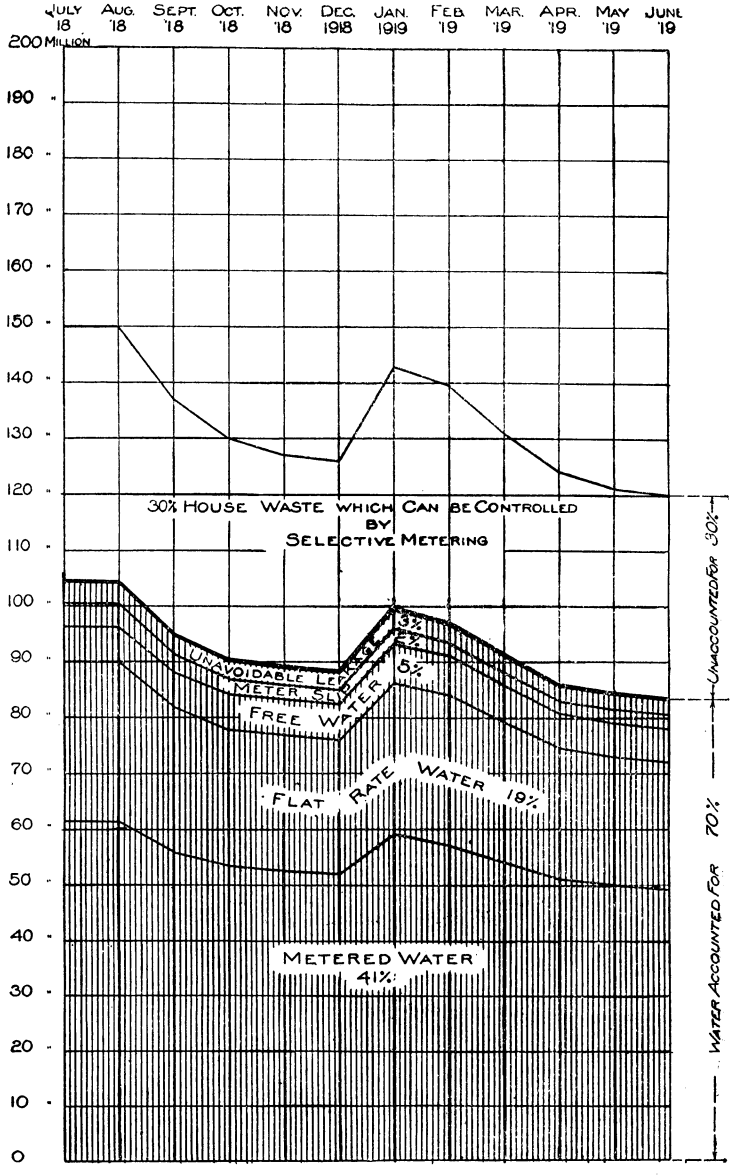

FIG. 8. SUBDIVISION OF USE AND WASTE OF WATER IN 1918–1919

opinion it is directly due to the low meter rate of 2 cents per thousand gallons which for a long time was the charge here. This, in conjunction with a fairly high minimum charge for a meter, made the average metered service user indifferent to the amount of water used. The larger consumer, as a rule, found it cheaper to waste water than to investigate for leaks. Buffalo is also a large railroad center and the city supplies all railroads with water. In 1917 the meter rate was raised to 4 cents per thousand gallons.

Nine-tenths of the city has now been covered by the survey with the following results:

Leaky fixtures reported and repaired	33,278
Leaky services reported and repaired	1,860
Unfinished supplies found wasting 3,587,000 gallons per day; broken mains and leaky joints wasting 4,376,000 gallons per day found and repaired	52

The services, broken mains, unfinished supplies and leaky joints repaired account for 12,000,000 gallons waste per day permanently stopped.

The pumpage has been reduced except in times of extremely hot or cold weather to less than 125,000,000 gallons per day, as compared to over 160,000,000 gallons per day in 1917. Figuring the cost of pumping at $6.24 per million gallons, the average cost for the last three years, the annual saving is $68,328. Against this is the estimated charge of $25,000 per year to maintain the pitometer division of the Bureau.

To date the survey has cost $96,931, much of which represents permanent investment in equipment and records or for professional services.

From the survey made and results obtained, it is evident that to a certain extent the house waste can be greatly reduced by house inspection controlled by pitometer measurements. When used in conjunction with selective metering the most flagrant house waste can be eliminated and the consumption reduced nearly to that obtained by universal metering and done at less expense. The pumpage can be reduced at least 20,000,000 gallons by the installation of 10,000 meters on house services where tremendous waste has been found by the survey. The installation of these meters is now proposed. A further reduction is not deemed advisable until a filtration plant is built.

A comparison between the cost of universal metering and the elimination and control of waste by the pitometer and selective metering is briefly as follows:

Control by pitometer and selective metering

Annual cost of inspection	$25,000.00
Installation of 10,000 meters, investment in meters $100,000	
Annual charge on meters, interest at 4½ per cent	4,500.00
Depreciation	4,000.00
Cost of reading and maintenance	6,000.00
Total annual cost	$39,500.00

Universal metering

Installation of 75,000 meters; investment in meters $750,000.00	
Annual charges on meters, interest at 4½ per cent	33,750.00
Depreciation 4 per cent	30,000.00
Cost of reading and maintenance	45,000.00
Total cost	$108,750.00

Annual saving in favor of pitometer control $69,250.

It is true that universal metering would reduce the consumption considerably more than the other method, but even if the reduction amounted to 20,000,000 gallons per day the saving in operation costs would not equal $69,250 per year.

The efficiency of any instrument is determined by how well it does what it is intended to do. If the object had been to reduce the consumption to a minimum the proper thing would have been to install meters and then eliminate underground waste by pitometer investigation. However, in any large water works there are certain features peculiar to it alone. For instance, the Buffalo Water Works had, at the time a reduction in pumpage was decided upon, two pumping stations capable of each supplying 150,000,000 gallons of water a day with mains properly built for distributing that quantity. If the pumpage is reduced to 110,000,000 gallons of water a day for nine months of the year, one plant can be shut down for that period. After that saving is effected, a further reduction in pumpage saves very little per million gallons pumped, as practically the same force is required to operate the plant whether

75,000,000 or 120,000,000 gallons is pumped, and irrespective of the pumpage, interest on the bonds accrues.

The intention was to reduce the pumpage from 159,000,000 gallons to less than 115,000,000 gallons by this survey and before the work is completed this result will have been attained. Moreover, the data have been furnished so it is known how to reduce the consumption further by intensive inspection and the installation of meters in certain districts.